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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 238

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ July 14, 1915.

SUGAR BEETS: PREVENTABLE LOSSES IN CULTURE.

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INTRODUCTION.

The cultivation of the sugar beet for the manufacture of sugar has been developed in Europe into one of the most important industries. This industry was transplanted thence into the United States, where the basis of labor costs and farm methods are quite different from those of Europe. Therefore, American beet growers must work out many problems in adjusting their cultural practices to their labor, soil, and climatic conditions.

It is of vital importance, if we are to compete successfully with other sugar-producing countries and secure the largest possible profit, that the cost of producing each ton of beets be reduced to a minimum.

Attention must be paid to details, in order to check the leaks responsible for low yields, for with sugar beets, as with most of our field crops, it is unfortunately true that the average yield per acre in the United States, despite its deep, rich soils, is lower than that of any European beet-growing country except Russia, as may be seen from Table I, which shows the yields for 1910 and 1911.

Doubtless climatic variations between one European country and another and between widely separated parts of the United States have a perceptible influence upon the yield, and it is extremely probable that the countries producing the heaviest yields are those in which the application of thorough cultural methods is the more general. It is also true of the United States, as compared with European countries, that the cost of labor is high and that land values are relatively low, one result of which is that much less labor to the acre is applied in this country than in Europe.

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TABLE I.—*Acreage of sugar beets and production of sugar of seven of the principal beet-growing countries.*[1]

Country.	Sugar production.	Area of sugar beets sown.	Yield of sugar beets per acre.	Sugar obtained from beets.
	Tons.	*Acres.*	*Tons.*	*Per cent.*
Germany	2,854,812	1,169,755	14.84	16.31
Russia	2,324,486	1,614,780	8.93	16.12
Austria-Hungary	1,678,566	913,159	12.38	14.85
France	783,925	571,805	10.63	12.90
Belgium	312,196	150,176	14.53	14.31
Holland	239,073	122,638	12.96	15.04
United States	510,172	398,029	10.17	12.61

[1] Compiled from the corrected figures of the International Association for Gathering Sugar Statistics. See Amer. Sugar Indus., v. 14, 1912, no. 1, p. 24; no. 2, p. 21.

STRIKING DIFFERENCES IN LOCAL YIELD.

One of the most striking facts in our agriculture is the enormous variation in yield obtained by different farmers in the same district, and often by near neighbors applying identical methods under similar soil and climatic conditions. These differences can not be attributed entirely to variations in soil, in climate, or in the methods themselves; nor, in the case of sugar beets, can they be accounted for by variations in the quality of the seed, because beet seed is invariably furnished by each sugar factory from its common stock. In many districts the seed is sown by the sugar company.

True enough, there are variations in soil and in methods, but these are not sufficient to account for the great discrepancies in yield everywhere to be observed. For example, within a small area under similar soil conditions, with identical climatic conditions and employing like methods, one may find a farmer rejoicing as he hauls 20 tons of beets from each acre to the factory, while his neighbor is almost too discouraged to load his pitiful 7 or 8 tons an acre into his wagon.

Of equal significance is the fact that while the yields from two or more individual fields may differ greatly, yet a glance over these fields after the foliage has attained some size, or even soon after thinning, might fail to reveal any appreciable difference in the stand. However, a careful examination of such fields would show that in general the plants in some fields are more widely spaced than in others and that gaps, not apparent at a distance, occur more or less frequently in the rows. Beet growers fail to realize the significance of these apparently small deficiencies in the stand.

In the course of field observations on sugar beets covering a period of several years, the local variations in yield were seen to be so remarkable that special studies were begun in order to ascertain the actual conditions prevailing in fields belonging to a number of representative beet growers in old established beet districts in Utah. These studies were commenced in 1910 and continued through the seasons

of 1911 and 1912, all of which seasons were favorable in that no unusual conditions arose, such as outbreaks of disease or invasions of insect pests; in other words, they might be called normal seasons.

Care was taken to select plats on groups of farms having similar soil conditions and where identical methods were employed. Climatic factors within each group were identical, since each group was located within a very restricted territory. Notes were made on the condition and preparation of the soil, of the dates of sowing, and of the various operations throughout the season. The farmers whose plats were under observation were not informed of the nature of the studies, but were left to carry on their operations in the accustomed manner.

Primarily, then, this is an attempt to reveal the actual conditions of commercial beet fields as they may be found in any average season in well-established beet districts and to ascertain whether any correlation exists between these conditions and the respective yields.

VARIATION IN STAND.

At an early stage of these observations a variation in the number of plants to the acre was discovered in the fields mentioned. This was quite as remarkable as the variation in yield. Furthermore, it became apparent that in the course of the season the percentage of stand progressively decreased to a surprising extent. The periods during which further losses in stand occurred indicated very clearly the chief factors concerned.

THREE TYPES OF SOIL STUDIED.

To discover the conditions prevailing on farms located on the principal types of soil, plats were selected on farms possessing in turn the following types: (1) Deep, sandy loam, well manured and in excellent tilth, where the farmers are accustomed to truck crops; (2) very light sandy loam, generally well manured and in good tilth, where intensive culture is practiced to some extent; and (3) heavy black loam, moderately well manured and in fair tilth, where general field crops are prevalent and much of the work is done by contract.

OBSERVATIONS IN 1910.

During the season of 1910 observations were made only in fields of heavy black loam, and no counts of the germination and thinning stands were taken, the data presented being based upon the condition of the harvest stands, accompanied by general notes during the season. These data are presented in Table II.

The small percentage of the harvest stands is startling. The major portion of this loss was due to careless spacing and thinning. The work was done by contract labor, with practically no supervision.

TABLE II.—*Analysis of observations made on beet plats and their yields in 1910, 1911, and 1912.*

Plat and character of soil.	Number of rows.	Length of rows.	Area of plat.	Germination stand.	Thinning stand.	Harvest stand.	Yield of plat.	Number of beets in plat.	Number of beets per acre.[1]	Average weight per beet.	Yield per acre.	Sugar in beet.	Purity.	Loss before thinning.	Loss by thinning.	Loss between thinning and harvesting.	Total loss or deficiency.	Actual average spacing of beets.	Date harvested.	Notes.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Season of 1910:		*Feet.*	*Acres.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*			*Lbs.*	*Tons.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*In.*		
Plat 1. Heavy black loam.	7	395½	0.1052	.....	.....	45.71	2,742	1,886	17,920	1.453	13.032	.....	.....	.....	.....	.....	54.29	17.5	Oct. 20.....	Plowed about 8 inches deep; contract labor; other conditions normal.
Plat 2. Heavy black loam.	7	395½	.1052	.....	.....	45.51	2,834	1,878	17,850	1.508	13.469	.....	.....	.....	.....	.....	54.49	17.5	.....do.....	
Plat 3. Heavy black loam.	10	273	.1043	.....	.....	39.58	2,417	1,619	15,520	1.492	11.586	.....	.....	.....	.....	.....	60.42	20.5	.....do.....	
Mean of 1910.....	.....	.....	.....	.....	.....	43.60	.....	.....	.....	.....	12.695	.....	.....	.....	.....	.....	56.40	18.5	.....	
Season of 1911:																				
Plat B. Sandy loam	8	150⅔	.0460	(2)	81.15	76.83	2,809	1,386	30,120	2.026	30.532	.....	.....	.....	18.85	4.32	23.17	10.4	Oct. 20 to 30.	See No. 1, Table III.
Plat A. Sandy loam	8	75⅓	.0230	(3)	86.68	64.41	616	581	25,250	1.06	13.391	.....	.....	.....	13.32	22.27	35.59	12.4	.....do.....	See No. 9, Table III.
Plat D. Sandy loam	8	150⅔	.0460	(4)	58.93	49.66	2,463	896	19,470	2.748	26.773	.....	.....	.....	41.07	9.27	50.34	16.3	.....do.....	See No. 3, Table III.
Plat C. Light sandy loam.	8	150⅔	.0460	(5)	87.80	.....	.....	.....	.....	.....	.....	.....	.....	.....	12.20	.....	.....	.....	.....	Data after thinning not available.
Plat E. Heavy black loam.	8	315	.0964	(6)	60.64	52.30	2,988	1,976	20,500	1.512	15.497	.....	.....	.....	39.36	8.338	47.70	15.1	Oct. 20 to 30.	See No. 15, Table III.
Plat F. Heavy black loam.	8	352	.1077	(7)	60.97	48.12	2,655	2,032	18,870	1.306	12.325	.....	.....	.....	39.03	12.85	51.88	16.6	.....do.....	See No. 16, Table III.
Plat G. Heavy black loam.	18	210	.1446	(8)	.....	45.62	5,005	2,586	17,880	1.935	17.306	.....	.....	.....	.....	.....	54.38	17.5	.....do.....	See No. 18, Table III.
Mean of plats:																				
A to D.....	.....	.....	.....	.....	78.64	63.63	.....	.....	.....	.....	23.565	.....	.....	.....	21.36	11.95	36.36	13.03	.....	
E to G.....	.....	.....	.....	.....	60.80	48.68	.....	.....	.....	.....	15.042	.....	.....	.....	39.19	10.59	51.32	16.40	.....	
All in 1911.....	.....	.....	.....	.....	72.69	56.155	.....	.....	.....	.....	19.304	.....	.....	.....	27.30	11.40	43.845	14.7	.....	

Season of 1912, group 1:																			
Plat 1. Light sandy loam.	4	330	.0505	87.93	54.36	46.99	2,780	930	18,420	2.990	27.524	17.30	90.00	12.07	33.57	7.37	53.01	17.02	Oct. 24	See No. 4, Table III.
Plat 2. Light sandy loam.	4	330	.0505	64.00	43.88	37.19	1,960	736	14,570	2.663	19.406	17.30	90.00	36.00	20.12	6.69	62.81	21.50	do	See No. 6, Table III.
Plat 3. Light sandy loam.	4	414	.0633	91.15	58.25	50.54	3,000	1,254	19,810	2.392	23.696	17.80	90.30	8.85	32.90	7.71	49.46	15.80	do	See No. 2, Table III.
Plat 4. Light sandy loam.	4	414	.0633	65.74	45.23	38.57	2,460	957	15,120	2.570	19.431	17.80	90.30	34.26	20.51	6.66	61.43	20.70	do	See No. 5, Table III.
Mean, group 1				77.20	50.43	43.32					22.514	17.55	90.15	22.79	26.77	7.11	56.68	18.75		
Season of 1912, group 2:																				
Plat 5. Very light sandy loam.	4	585	.0895	94.67	79.65	77.11	4,230	2,705	30,220	1.564	23.631	19.60		5.33	15.12	2.54	22.99	10.4	Oct. 27	Soil not so deeply plowed as in plats 1, 2, 3, and 4, but more sandy; owner's labor and supervision.
Plat 6. Sandy loam	4	268	.0410	93.16	73.15	68.20	1,710	1,096	26,730	1.560	20.853	18.50		6.84	20.01	4.95	31.80	11.7	Oct. 22	
Plat 7. Loam	4	515	.0788	72.64	63.75	59.82	2,690	1,848	23,450	1.455	17.068			27.36	8.89	3.93	40.18	13.5	Nov. 6	See No. 11, Table III.
Plat 8. Very light sandy loam.	6	306	.0702	87.53	65.30	60.26	2,420	1,658	23,600	1.459	17.236	17.80		12.47	22.23	5.04	39.74	13.3	Sept. 28	See No. 10, Table III.
Plat 9. Very light sandy loam.	4	390	.0596	78.33	60.25	52.48	1,660	1,226	20,570	1.354	13.926	18.00		21.67	18.08	7.77	47.52	15.2	Sept. 20	Much of the work done by boys, with little supervision.
Mean, group 2				85.26	68.42	63.57					18.543	18.47		14.73	16.86	4.84	36.44	12.8		
Season of 1912, group 3:																				
Plat 10. Heavy black loam.	10	320	.1224	80.05	68.35	63.13	2,340	3,029	24,760	0.772	9.558	15.20	89.60	19.95	11.70	5.22	36.87	12.6	Nov. 28	See No. 13, Table III.
Plat 11. Heavy black loam.	8	277	.0847	89.04	67.20	60.12	2,585	1,996	23,570	1.295	15.253	18.90	89.90	10.96	21.84	7.08	39.88	13.3	do	Owner's labor; conditions about normal.
Plat 12. Heavy black loam.	8	309	.0945	76.13	49.29	37.98	2,227	1,407	14,890	1.580	11.733	18.00	88.60	23.87	26.84	11.31	62.02	21.1	Oct. 20	Contract labor; conditions about normal.
Plat 13. Heavy black loam.	8	332	.1016	68.50	42.00	29.55	2,096	1,177	11,580	1.780	10.314	19.95	90.85	31.50	26.50	12.45	70.45	27.4	Oct. 17	See No. 22, Table III.
Mean, group 3				78.43	56.71	47.69					11.714	18.01	89.74	21.57	21.72	9.01	52.30	18.6		
Mean of all, 1912				80.68	59.28	52.46					17.679	18.01	89.94	19.31	21.41	6.82	47.55	16.4		

[1] Correct to 25 beets or less per acre.
[2] Good; gaps due to faulty dr ill.
[3] Irregular, spotty.
[4] Fair, irregular.
[5] Good, but rather spotty.
[6] Only fair.
[7] Rather poor.
[8] Fairly good.

OBSERVATIONS IN 1911.

During the season of 1911 general notes were made of the germination stands without actual measurements or counts. Seven fields were kept under observation, including soil types 2 and 3, namely, light sandy loam and heavy black loam. These data also are presented in Table II.

OBSERVATIONS IN 1912.

During 1912 the studies were extended to include all three types of soil. Careful notes were made of the germination stand prior to thinning. The selected rows extended entirely across the field in each instance. The data obtained are shown in Table II.

ANALYSIS OF OBSERVATIONS.

The analysis of observations for the season of 1910, as presented in Table II, shows a complete correlation between yield and percentage of stand. The small percentage of the ultimate stand is surprising, the mean being only 43.6 per cent, and, although the average weight of the beets is 1.453, 1.508, and 1.492 pounds, respectively, the excess over 1 pound did not nearly compensate for the large area occupied by each plant. This deficiency of stand was caused largely by careless spacing and thinning. All the work was done by contract labor with practically no supervision. The plats were in adjacent fields, where the general conditions and cultural operations were almost identical.

The harvest stands for 1911, though appreciably better than those shown by the plats of 1910, exhibit a mean of only 56.155 per cent (Table II). The correlation between stand and yield is rather obscured by the special factors which developed during the season on several plats. However, these factors throw additional sidelights on the studies, since their influence on yield is very apparent. For example, on plat A the cultural operations were left almost entirely to young boys, without oversight. The thinning was very carelessly done, 6.89 per cent of the plants being left in pairs, which, for practical purposes, means their entire loss. Weeds were allowed to choke the beets for a great part of the season. On the other hand, the owner of plat B is well known to be a fine truck grower, who does all the work with the assistance of his own family. The soil. through years of intensive farming, is very deep and mellow.

Plat D is located on much lighter soil than plat B, but with a stand of considerably lower percentage it yielded almost as much for each acre. This, in connection with the record of plats 1, 2, 3, and 4, of 1912, brings out the fact, which is contrary to the prevailing notion, that beets will yield more heavily in deep light sandy soils if they are well manured than in the somewhat heavy loams that have been regarded as more typical beet soils.

Plat E shows a fairly normal correlation between stand and yield, while plat F decreases on account of late and careless thinning, no less than 9.82 per cent of pairs of plants being found.

Plat G shows a greater yield than plat E, because its soil was very well prepared and manured and the cultural work done by Japanese who were working for themselves.

Referring to the analysis of observations for the season of 1912, as presented in Table II, the plats in group 1 were operated under almost experimental conditions. The seed was sown under the direction of the writer. Two pairs of plats were studied, one pair in each of two contiguous fields possessing very uniform soil. One farmer worked plats 1 and 2 while another farmer worked plats 3 and 4. The rows extended entirely across each field. The two farmers carried on or supervised all the cultural operations. The only appreciable difference in the handling of the plats was that the seed was sown slightly deeper in one plat of each pair than in the other. This resulted in more damping-off in the deeper sown plats, thus producing therein rather poorer stands. In this group the correlation between yield and stand is complete. From this group and plat D of 1911 it would appear that the optimum area per plant is considerably greater in deep, light, well-manured sandy soils than in loams and heavy loams. In group 2 a perfect correlation is shown between yield and stand. At the same time, the effect of inexperience and lack of supervision is evident in plat 9. In group 3 the correlation between stand and yield actually is accentuated by the exception shown in plat 10. This discrepancy is entirely accounted for by the adverse conditions to which this plat was subjected.

CORRELATION OF STAND AND YIELD.

In Table III all the plats for the three years are arranged according to the percentage of the harvest stand, beginning with the highest. They are divided into three groups, representing three soil types. In this table the percentage of the harvest stand is placed side by side with the yield of each plat. This reveals a striking correlation between the percentage of stand and the yield. The apparent exceptions are accounted for by the special conditions described under the heading "Notes" in Tables II and III. Upon allowing for the adverse or especially favorable conditions mentioned, it may be said that the correlation is complete.

In Table III the means of the yields of groups 2 and 3 exhibit a ratio almost exactly equal to the relation of their respective stands. Based on the figures given, the mean yield of group 3 would be 17.72 if the stand were the same as in group 2.

TABLE III.—*Comparison of the harvest stands and the yields of sugar beets for the seasons of 1910, 1911, and 1912.*

Reference No.	Plat and season.	Notes.	Harvest stand.	Yield per acre.
	Group 1.—Deep sandy loam:		*Per cent.*	*Tons.*
1	Plat B (1911)	Deep, well-manured soil; crops rotated; owned and worked by experienced truck farmer.	76.83	30.532
2	Plat 3 (1912)	Rather deeply worked, well-manured soil, in good tilth; crops rotated; Nos. 2 and 5 in same field—very uniform, contiguous to the field in which Nos. 4 and 6 are located.	50.54	23.696
3	Plat D (1911)	Deeply worked soil, in fine tilth; crops rotated; owner's labor and supervision.	49.66	26.773
4	Plat 1 (1912)	Very deeply worked, well-manured soil; crops rotated; blocking and thinning done by contract, all other labor done by owner; Nos. 4 and 6 in same field—very uniform.	46.99	27.524
5	Plat 4 (1912)	Same as No. 2, except that seed was sown rather deeper, resulting in more damping-off in the spring.	38.57	19.431
6	Plat 2 (1912)	Same as No. 4, except that seed was sown rather deeper, resulting in more damping-off in the spring.	37.19	19.406
	Group 2.—Very light sandy loam:			
7	Plat 5 (1912)	Soil not plowed so deeply as in Nos. 2, 4, 5, and 6, but more sandy; owner's labor and supervision.	77.11	23.631
8	Plat 6 (1912)	....do....	68.20	20.853
9	Plat A (1911)	Very badly thinned, spacing irregular, 6.89 per cent of the plants in pairs; choked with weeds; labor mostly done by young boys without supervision.	64.41	13.391
10	Plat 8 (1912)	Plants tardy in the spring, owing to late sowing; soil in good tilth; owner's labor; good farmer.	60.26	17.236
11	Plat 7 (1912)	Second sowing; plants rather tardy in the spring; soil in good tilth; owner's labor; good farmer.	59.82	17.068
12	Plat 9 (1912)	Much of the work done by boys, with little supervision.	52.48	13.926
	Group 3.—Heavy black loam:			
13	Plat 10 (1912)	Ground not plowed, only disked and harrowed; severe hailstorm in mid-August defoliated the beets.	63.13	9.558
14	Plat 11 (1912)	Owner's labor; conditions about normal...	60.12	15.253
15	Plat E (1911)	Land in good tilth; too much contract labor; 2.56 per cent of the plants in pairs.	52.30	15.497
16	Plat F (1911)	Sowed and thinned rather late, thinning badly done; 9.82 per cent of plants in pairs; contract labor.	48.12	12.325
17	Plat 1 (1910)	Contract labor; soil plowed about 8 inches deep; other conditions normal.	45.71	13.032
18	Plat G (1911)	Soil in good tilth, heavily manured, deeply plowed; Japanese working for themselves.	45.62	17.306
19	Plat 2 (1910)	Like No. 17....	45.51	13.469
20	Plat 3 (1910)	....do....	39.58	11.586
21	Plat 12 (1912)	Contract labor; conditions about normal..	37.98	11.733
22	Plat 13 (1912)	Contract labor; 2.03 per cent loss by cutting an irrigation ditch through the plat; other conditions normal.	29.55	10.314
	Mean of group 1		49.96	24.562
	Mean of group 2		63.71	17.684
	Mean of group 3		46.76	13.007
	Mean of all plats		52.26	17.432

SOURCES OF LOSS IN STAND.

Sources of losses of great magnitude in the stand are brought to light by an examination of the data presented in Table II. The factors directly causing a decrease in the number of plants to the acre were found to be susceptible of arrangement into three groups,

namely: (1) Those occurring in the germination stand prior to thinning; (2) careless and improper thinning and blocking; and (3) those incidental to cultural operations between thinning and harvest.[1]

SOURCES OF LOSS IN THE GERMINATION STAND.

The sources of loss found between the time of sowing and the dual operation of spacing and thinning are (1) poor preparation of the seed bed; (2) imperfect operation of seed drills; (3) late frosts; (4) the damping-off disease; (5) the blowing of light, sandy soils; (6) flea beetles; and (7) cutworms or wireworms.

LOSSES IN STAND FROM THINNING.

Improper thinning was found to be the greatest single source of loss in stand, the more serious because nearly imperceptible and unsuspected. This loss is caused by the double operation of blocking and thinning. It is one of the most costly operations in the cultivation of sugar beets and, strange to say, the one most frequently intrusted to hired labor or contract work. Worse still, it is seldom efficiently supervised. Invariably the space left between the plants is greater than the farmer imagines or intends. When the plants have attained a moderate size, it is almost impossible to distinguish, without counting, between stands of 50, 60, or 80 per cent.

LOSSES IN THE HARVEST STAND.

The difference in the percentage of stand between that shown immediately after thinning and that existing at harvest time is to be attributed to inefficiency in the cultural operations during the intervening period. Some of these losses are caused by the eradication of plants with the hand hoe and their destruction by the hoofs of horses or by implements, especially when turning at the ends of rows, and by poor guidance of the cultivator, whereby it swerves and cuts out the plants along the rows. (In this way from one to four rows may be damaged at each round, according to the type of cultivator employed.) The flooding of low areas and the drying out of high ones, as well as cutting through rows to distribute water in poorly graded fields, are additional sources of loss. (See Table II.)

It soon became apparent that the observations could most profitably be confined to a determination of the nature and extent of losses in stand and their causes. From these data it appeared possible to discover whether correlations exist between such losses and the yield of the respective plats.

To ascertain the percentage of the stands throughout the season, measurements were made of the actual distance between all the plants in every row under observation, instead of obtaining merely the aver-

[1] Germination stand is the stand of beets resulting from the germination of the seed up to the time of thinning. Thinning stand is the stand or number of plants left after blocking and thinning. Harvest stand is the number of beets to the acre at harvest time.

age distance by counting the plants in each row and dividing the length of the rows by the number of plants. This was accomplished with the simple contrivance shown in figure 1.

THE SIGNIFICANCE OF POOR STANDS.

Having shown that progressive reductions in the percentage of stand occur throughout the entire season, and having indicated the factors chiefly concerned in this destruction of plants, an inquiry may be made as to the significance of these reduced percentages. Does the eradication of these beets from time to time during the season affect the ultimate yield, or does it happen that the remaining beets, being more widely spaced, so increase in size on account of the augmented area allowed to each plant as to compensate for the diminished number to the acre?

FIG. 1.—Graduated wooden rod used in measuring the gaps in a stand of sugar beets.

It is frankly conceded that evidence on this question might be inconclusive if based alone on observations of plats or fields on ordinary farms—that is, farms among which greater or less diversity of conditions exist, however much care may have been exercised in their selection; where the application of even identical methods will vary to some degree; and where there are other factors of variation known to everyone who has carried on such experiments. Fortunately many experiments have already been conducted under test conditions, both in Europe and in the United States, which conclusively demonstrate that with such crops as cotton, corn, mangel-wurzels, potatoes, turnips, carrots, lettuce, sugar beets, and other spaced crops an optimum area for each plant may be discovered. Only a few of these are cited.[1] To

[1] Holden, P. G., and Hopkins, C. G. The sugar beet in Illinois. Ill. Agr. Exp. Sta. Bul. 49, 52 p. illus., 1898.
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reduce or to increase that area beyond certain limits results in a lessened yield per acre. Each crop requires its own special area per plant to yield the best results, but that area must be modified to some extent in different soils, with the available water supply and with climatic variations.

The cited experiments and practical experience alike show that the sugar beet requires, not only for the highest tonnage but also for the greatest yield of sugar per acre, an area of 144 to 160 square inches per plant, the optimum area varying somewhat with the character of the soil, fertilizers, and climate. In practice, the rows should be spaced not less than 18 or 20 inches apart, to facilitate cultural operations with horse implements. Commonly a distance of 20 inches has been adopted in the United States. This, then, is really a closed question. The spacing may be arranged by adjustment of the seed drill. The matter of importance is the spacing between the plants in the rows.

In most localities and in good beet soils a distance of 8 inches between plants is advised. Each beet would thus have 160 square inches, which, in round numbers, would give 39,200 plants per acre. This might be taken to represent a perfect stand and is the one employed in these tables as the standard for comparison. With beets averaging the moderate weight of 1 pound, such a stand would yield no less than 19.6 tons to the acre. In most of the beet districts of the United States the average weight of beets considerably exceeds this; it does so in all but one of the plats under observation. (See Table II, column 11.) We have seen that the average acre yield in this country during the season of 1910–11 was only 10.17 tons and that of Utah 11.42 tons, as compared with an average yield of 14.84 tons to the acre in Germany.

Since these facts have been experimentally established under test conditions, the data presented in Tables II and III acquire a real significance. Granting the impossibility of obtaining absolutely uniform conditions among the plats, even of each group, it would be unreasonable and illogical to repudiate the strong correlations found each season and to call them mere coincidences. One must acknowledge them to be examples of cause and effect. In short, it is held that the losses in stand indicated in these tables correspond more or less closely to the diminished yields.

As before stated, the apparent exceptions are accounted for by the specific adverse or especially favorable conditions mentioned in relation to them. The evidence of a relationship between the percentage of stand and the percentage of yield is strengthened to a degree almost equaling that obtained under strict experimental conditions by the fact that the data from two pairs of plats are presented, one pair being in each of two very uniform contiguous fields

where all the cultural operations were identical and carried on in each field by the same person. These are plats 1 and 2 and plats 3 and 4 of group 1, 1912. (See Table II.) In these two pairs of plats the correlation is perfect.

From these data, then, grave losses have been revealed in the percentage of stand of sugar beets. It has been demonstrated that a close relation exists between stand and yield; therefore it is apparent that such considerable losses in stand as have been indicated represent losses in tonnage. If data were collected from the fields of less experienced beet growers, still greater discrepancies would be revealed, which would correspond somewhat closely to their discouraging yields. Most of these losses are avoidable.

LOSSES ON A CASH BASIS.

The discrepancies among the yields of the fields under consideration will appear still more striking if translated into terms of dollars and cents. It is known that year after year some beet growers in the older districts (for example, those represented in groups 1 and 2, Table II) obtain no less than 30 tons of beets per acre, while in the district represented by group 3 (Table II) a yield of 25 tons an acre is not uncommon. Large yields are obtained annually by the most skillful beet growers in other States. It is acknowledged that yields such as those just mentioned are exceptional and are won only after the soil has been worked into splendid tilth by very deep plowing, ample manuring, and intensive culture. Perhaps such a standard might be open to the criticism that like results would be impracticable in general. For the purposes of comparison, then, the best plat in each group will be used. (See Table IV.)

Emphasis is placed on the fact that the yields mentioned in connection with the fields under consideration are not unusual, but are obtained by the same growers year after year with but slight fluctuation. Should it be contended that the soil in these fields is richer, deeper, or more fertile than that of other fields in the vicinity, where much smaller yields are obtained, it can be said of them that they are so chiefly because the owners or cultivators of those fields have brought them up to their present condition through better farming practices and not because the soil itself was markedly superior at the outset.

In regard to the sugar content of the beets, it can be said that the percentages quoted are those obtained from composite factory samples taken at random at the time of the delivery of the beets and determined by the chemist of the sugar factory. The season of 1912, when these tests were made, was not an exceptional one. It is undoubtedly true that weather conditions, especially in the latter part of the season, influence perceptibly the percentage of

sugar in the beet. However, it is also true in general that the beets of those growers who are skillful enough to obtain the best yields also show a relatively high percentage of sucrose. In some States the average percentage of sugar is annually lower than in others, probably on account of climatic differences. For that reason the standard set in this paper might have to be lowered somewhat to meet local conditions. In such places the standard obtained from the best beet growers in any specified locality could be substituted as a basis for calculating the deficiencies among the less successful beet growers.

There are two systems of payment in vogue, namely, the flat rate and the sliding scale. The flat rate adopted in this paper is below the average for the whole country, namely, $5 a ton for all beets containing more than the factory minimum of sucrose. The average price during 1913–14 was nearer $6 a ton.

TABLE IV.—*Comparison of the yields and cash receipts from various plats of sugar beets, for 1910, 1911, and 1912.*

Group and plat.	Year.	Actual yield.	Sugar in beet.	Actual returns.		Deficiency, on basis of yield of best plat.[1]	
				Flat rate.	Sliding scale.	Flat.	Sliding.
1	2	3	4	5	6	7	8
Group 1:		*Tons.*	*Per cent.*				
Plat B	1911	30.532	.....	$152.66	.....	.....	.....
Plat 3	1912	23.696	17.80	118.48	$131.27	$34.18	.....
Plat D	1911	26.773	.....	133.86	.....	18.80	.....
Plat 1	1912	27.524	17.30	137.62	148.35	15.04	.....
Plat 4	1912	19.431	17.80	97.15	107.64	55.51	
Plat 2	1912	19.406	17.30	97.03	104.62	55.63	.....
Mean	.....	24.560	17.55	122.80	122.97	35.83	.....
Group 2:							
Plat 5	1912	23.631	19.60	118.15	143.67	.....	.....
Plat 6	1912	20.853	18.50	104.26	119.90	13.89	23.77
Plat A	1911	13.391	.....	66.95	.....	51.20	.....
Plat 8	1912	17.236	17.80	86.18	95.48	31.97	48.19
Plat 7	1912	17.068	.....	85.34	.....	32.81	.....
Plat 9	1912	13.926	18.00	69.63	77.98	48.52	65.69
Mean	.....	17.684	18.475	88.42	109.26	35.68	45.88
Group 3:							
Plat 10	1912	9.558	.....	47.79	.....	38.74	.....
Plat 11	1912	15.253	18.90	76.26	89.53	10.27	.....
Plat E	1911	15.497	.....	77.48	.....	9.05	.....
Plat F	1911	13.325	.....	66.62	.....	19.91	.....
Plat 1	1910	13.032	.....	65.16	.....	21.37	.....
Plat G	1911	17.306	.....	86.53	.....	0	.....
Plat 2	1910	13.469	.....	67.34	.....	19.19	.....
Plat 3	1910	11.586	.....	57.93	.....	28.60	.....
Plat 12	1912	11.733	18.00	58.66	65.70	27.87	.....
Plat 13	1912	10.314	19.95	51.57	63.74	34.96	.....
Mean	.....	13.007	18.95	65.53	72.99	21.00	.....
Mean of all plats	.....	17.433	18.27	87.39	104.35	28.38	.....

[1] In groups 1 and 3 the percentage of sucrose in the beets from the best plats is not known; therefore, the computations of receipts under the sliding scale can not be given for those groups.

For the sliding scale $5 a ton for beets containing 16 per cent of sucrose, with 30 cents a ton additional for every increment of 1 per cent in sugar content and a deduction of 25 cents a ton for every 1 per cent less than 16 per cent (fractional percentages in proportion), is taken to represent about the average rate.

A consideration of columns 5, 6, and 7 of Table IV will reveal the surprising magnitude of the discrepancies as compared with the yields of the best growers. In some cases this discrepancy is greater per acre than the actual cost of producing the crop, which averages about $42.50 an acre exclusive of manure, rent, or interest on the capital invested. The additional cost of manure would be about $15 to $20 an acre, but as this should preferably be applied to a preceding crop instead of directly to the beets this charge would be shared between two crops.

HOW TO OBTAIN BETTER STANDS.

Grave sources of loss have been revealed. They occur not among poor farmers alone, as might have been expected, but among those considered to be good. How great these losses are among the less successful farmers may be surmised after a moment's consideration. The average yield per acre of sugar beets in the United States for the season of 1910–11 was only 10.17 tons; the average for the State of Utah where these observations were made during the same period was 11.42 tons to the acre, while that among the better farmers as taken from these plats was 17.68 tons. Year after year the best beet growers obtain from 20 to 25 tons an acre. (Pl. I.) Therefore a large army of beet growers must obtain an average yield of much less than 10 tons an acre. Either their land is unsuited to profitable beet culture or their methods are bad or are very inefficiently carried out. In any case the real nature of the trouble should be ascertained. If the land is not adapted to beet culture, it would seem better to abandon that crop for a more profitable one; if their methods are at fault, the growers should be instructed by the factory field men.

To analyze data of this character and to indicate the causes of deficiency in stands of sugar beets, with the accompanying losses, are almost tantamount to pointing the way to an avoidance of such losses.

GERMINATION LOSSES.

The average loss of stand caused by imperfect germination was 19.31 per cent (Table II, column 5), which was due largely to the poor preparation of the seed bed. In the first place, it was noted that fall plowing is seldom practiced and that it is rarely deep enough. One serious result of shallow plowing, early apparent in beet culture, is that weed seeds remain so near the surface that they are enabled

to germinate and sprout before the beet seedlings appear above ground, greatly retarding and stunting the latter. (Pl. II.)[1]

Too frequently manuring is delayed until spring, when, in conjunction with faulty preparation of the ground, pockets of half-rotted manure are left in the soil. These cause the taproots of seedling beets coming in contact with them to become sprangling and ill-shaped. It is believed to be the best practice to apply manure to a preceding crop instead of directly to beets.

In irrigated districts much loss is occasioned by the imperfect grading and leveling of the surface of the field; thus, low spots remain in some places and high ones in others. The low areas are

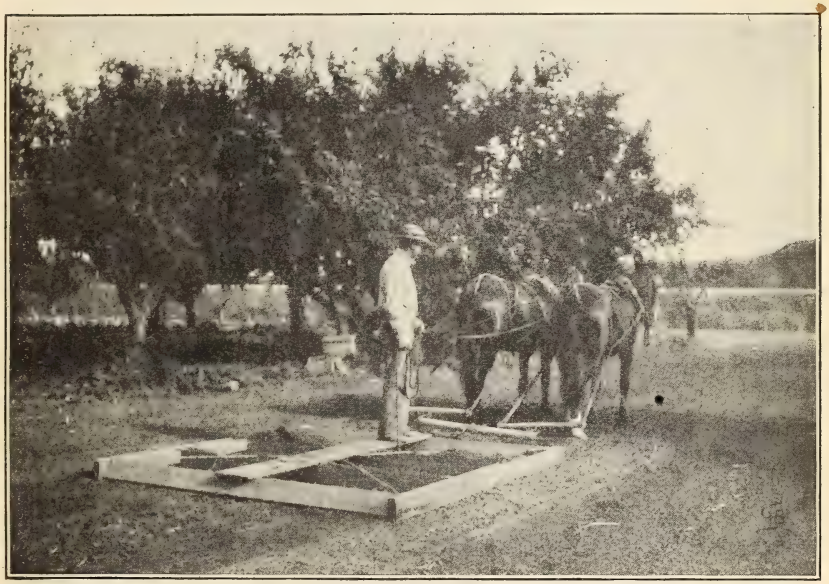


FIG. 2.—A homemade float used in leveling a beet field preparatory to sowing the seed.

flooded with every irrigation (Pl. III), while the elevated places, if extensive, suffer drought or render much extra work necessary to get the water over them. In either case, many plants are killed (fig. 3).

It is also apparent that losses in the stand occur on account of lack of responsiveness of the seed drills to irregularities in the surface of the field, resulting in the scattering of seed on the surface of the ground when individual drills pass over depressed areas. Little or none of the uncovered seed germinates; if the seed were slightly covered it might lie there in the dry surface soil until a shower caused

[1] The subsequent operations of disking, harrowing, and floating the fields (fig. 2) are not sufficiently thorough, leaving the seed bed too rough and cloddy and resulting in a reduced percentage of germination of the beet seed.

it to germinate later. Such belated plants add little to the tonnage. (Pl. IV.)

The damping-off disease exacts its toll every season; it may be so severe as to more than decimate the stand (Pl. V). It is occasioned partly by fungi borne on the seed balls, and partly by fungi present in the soil. This disease seems to be severe when the spring weather is unfavorable for the rapid and vigorous germination and growth of the beets.

An incrustation of the soil after rains sometimes prevents the young seedlings from breaking through, especially in heavy loams. These

FIG. 3.—Three sugar beets, showing the effect of standing water or a wet subsoil upon the roots.

crusts may with advantage be broken with a corrugated roller. (Pl. VI.)

Wireworms and flea beetles are very troublesome and destructive in some localities (fig. 4). In this connection it would be of benefit to keep down weeds along fences, ditches, and roadsides. (Pl. VII.)

It is entirely practicable to increase the percentage of the germination stand to an extent that would amply repay the cost of the additional labor required. Deeper plowing should be more generally practiced. The extra disking and harrowing would require only a few hours more labor per acre. In irrigated regions the extra labor

A Good Stand of Sugar Beets, which Will Yield about 20 Tons to the Acre, from a Practically Perfect Germination Stand.

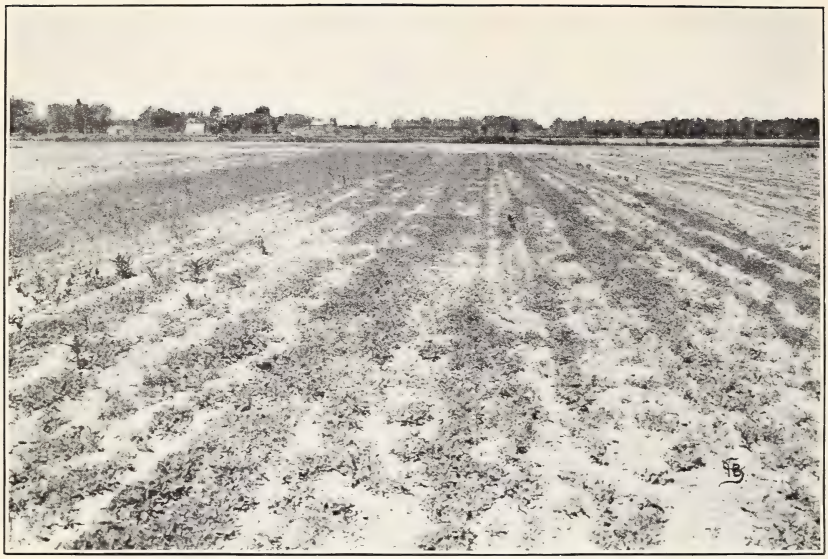


FIG. 1.—A SHALLOW-PLOWED BEET FIELD.

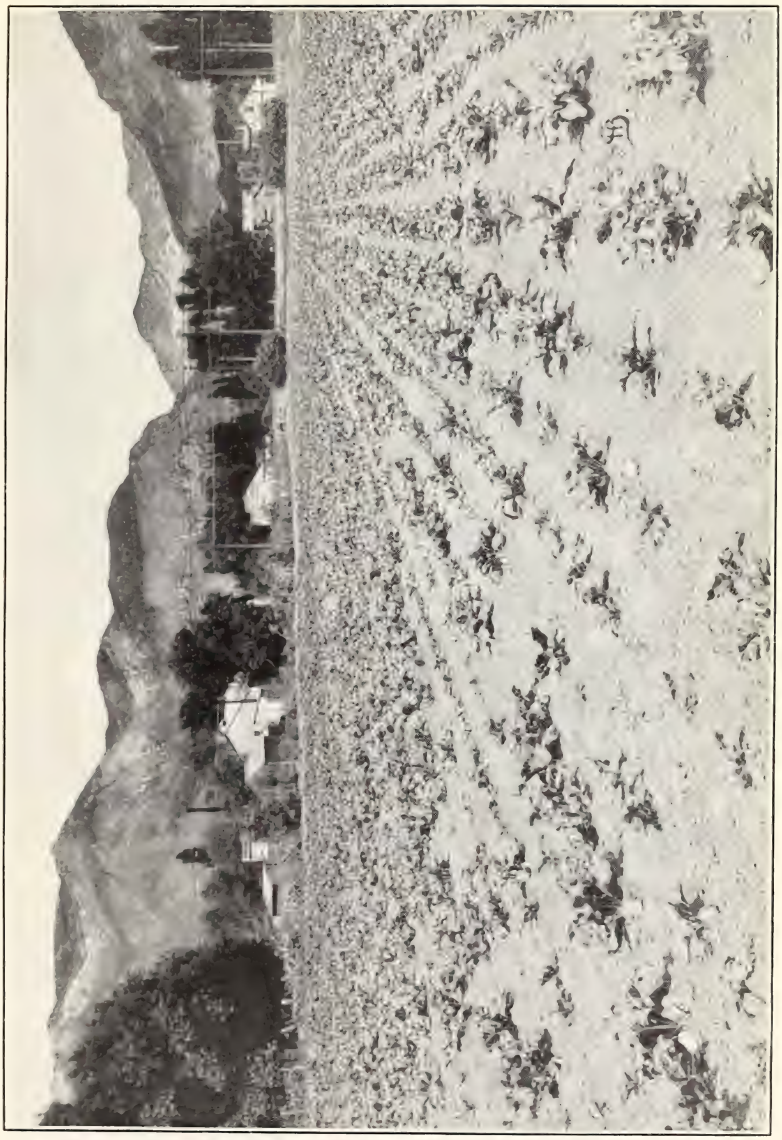
FIG. 2.—A DEEP-PLOWED BEET FIELD.

CONTIGUOUS SHALLOW-PLOWED AND DEEP-PLOWED FIELDS, SHOWING THE EFFECT OF EACH METHOD ON WEEDS.

Shallow plowing leaves the weed seeds near the surface, where they spring up before the beet seeds, checking and choking the young beet seedlings. Deep plowing buries the weed seeds and gives the beets an opportunity to get started before they come up.

A Poorly Leveled Beet Field that Involves Much Unnecessary Labor during Irrigation, and which Allows the Beets to be Killed on the Flooded Low Spots.

A FIELD OF SUGAR BEETS, SHOWING THE GAPS LEFT IN THE ROWS BY A DRILL WHICH FAILED TO ADJUST ITSELF TO THE IRREGULARITIES IN THE SURFACE OF THE GROUND.



A STAND OF SUGAR BEETS MUCH REDUCED BY DAMPING-OFF.

A HOMEMADE ROLLER USED TO COMPACT THE SOIL ABOUT THE ROOTS OF SEEDLINGS AND TO BREAK UP THE CRUST THAT SOMETIMES FORMS AFTER EARLY SPRING RAINS.

YOUNG SUGAR BEETS INJURED BY WIREWORMS.
The worm shown at the right is twice natural size.

A FIELD OF SUGAR BEETS, SHOWING THE EFFECTS OF LATE THINNING.

A, Thinned at the proper time; *B*, just thinned, several weeks after the first plat; *C*, not yet thinned and badly choked with weeds.

necessary to grade and level a field properly could be put in at odd times during the autumn and winter and in many cases would not cost more than the additional labor and loss entailed each season by leaving this work undone.

Implement manufacturers should be urged to study the improvement of seed drills in order to make them more responsive to the surface of the ground and to perfect a seed-dropping device for them. However, much of the trouble with seed drills could be avoided by better preparation of the seed bed.

The first cultivation, taking place soon after the seedlings appear, is sometimes carelessly done or is performed with implements not well adapted to the operation. Thus, many seedlings are smothered by having the soil thrown over them. A special type of cultivator, with disks adjusted to protect the plants, will prevent losses of this sort (fig. 5).

FIG. 4.—Sugar-beet seedlings, showing the effect of late frosts and the bites of flea beetles. The dead seedlings were killed by frost; the others were bitten by flea beetles.

LOSSES ON THE THINNING STAND.

Many beet growers defer thinning and spacing too long. The European beet growers hasten to their fields as soon as most of the seedlings have acquired two pairs of true leaves. To delay beyond this stage may mean a marked reduction in tonnage and sugar, as is shown by an experiment in Germany in which the results given in Table V were obtained.[1]

TABLE V.—*Losses due to delayed thinning of sugar-beet seedlings in Germany.*

Thinned—	Yield.	Loss per acre at $5 a ton.
	Tons.	
At the proper time	15	
One week later	13.5	$7.50
Two weeks later	10	25.00
Three weeks later	7	40.00

[1] Robertson-Scott, J. W. Sugar Beet: Some Facts and Some Illusions, p. 120. London, 1911.

In general, the larger the plants when thinned the greater the shock they receive, and the weeds meantime have an opportunity to outstrip the beets, crowding and checking them. (Pl. VIII.)

However, the greatest single cause of deficiency in stand is careless or improper spacing and thinning. As shown in column 16, Table II, the average loss entailed in the plats under observation was 21.41 per cent. It is significant that this dual operation, one of the most expensive in beet culture, is very frequently done by contract labor either without supervision or with the most perfunctory and intermittent kind of supervision. In European beet fields this operation is under constant supervision.

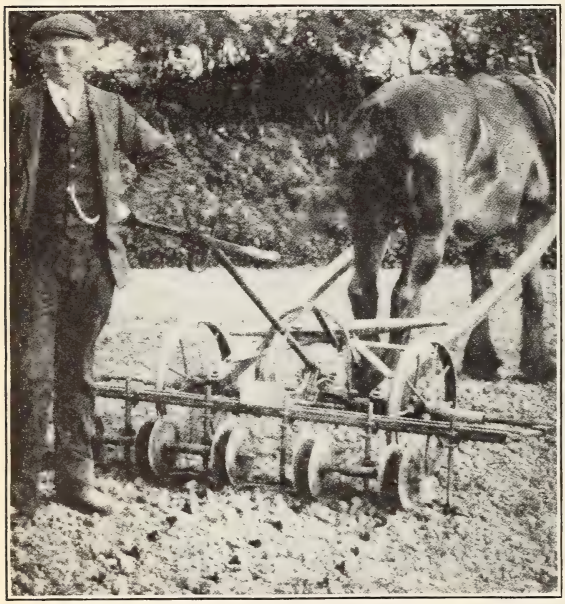


FIG. 5.—A beet cultivator with disks to prevent the seedlings from being covered by the earth thrown up by the cultivator blades. (Courtesy of J. W. Robertson-Scott, London, 1911.)

The deficiency of stand caused by this operation is brought about by spacing the plants too far apart, by leaving two or more plants together, or by carelessly chopping out plants where they should be left. In no instance has the writer been able to find the spacing as close as the beet grower intended or imagined. An increase of 2 or 3 inches in the distance between all the plants would greatly reduce the yield per acre, other things being equal. This excessive spacing is generally unsuspected and imperceptible except by actual measurement.

Yet one can scarcely blame hired or contract laborers for hurrying over this work, because in most cases they are paid the same price per acre whether the work be well or badly done and whether the stand be good or poor. It would seem but equitable to offer a bonus for better work, based on the number of plants per acre remaining after thinning. On the celebrated farm of Sainte Suzanne, belonging to the Prince of Monaco—a farm worked on scientific principles—it is required that the beets be left 11 inches apart in the row. About 40 cents additional per acre is paid if 28,000 beets an acre remain after the second cultivation.

The highest percentage the writer has attained by the careful use of a 6-inch hoe was 92.58 per cent for one row. His best average for 8 rows was 83.7 per cent, when working with moderate rapidity.

ELIMINATION OF HAND SPACING.

Although it is believed that the singling of beets will never be accomplished with machines or implements, it is thought to be entirely practicable to effect the spacing in such a manner.

In this country of high-priced labor, means should be devised to eliminate hand labor from farming operations as far as possible. Much has been accomplished already toward the successful pulling and topping of beets by machinery. A number of machines for blocking beets have been patented, and some of them are in successful operation. In some parts of Europe a 4-row or 6-row cultivator is run across the field at right angles to the rows, thus cutting out spaces at regular intervals. Generally, this spaces the beets too widely. Numerous attempts have been made in the United States to accomplish proper spacing by transplanting sugar-beet seedlings in the manner that tobacco, cabbage, celery, etc., are successfully set out. However, it has been thought that this causes the beets to become sprangling, by injuring or turning up the taproots of the young plants.

LOSSES AFTER THINNING AND BEFORE HARVESTING.

Individually, the losses occurring between the times of thinning and harvesting are of minor importance, although they aggregated 6.82 per cent among the plats under observation during the season of 1912. (See Table II, column 17.) A source of loss present every season, especially among less experienced beet growers, is that arising from the careless or unskilled use of the cultivator, not only when turning at the ends of rows, but in the rows themselves, by allowing the cultivator to swerve far enough to cut out plants. With a 2-row or 4-row cultivator this may occasion a serious loss, because two or four rows are injured simultaneously. It need only be said that a little more care would appreciably reduce this loss.

The later in the season that the various depletions in stand are made, the more serious is their effect on the yield, because the plants then have less chance to respond to space effect by an additional increase in size.

LOSSES FROM THE DRYING OF BEETS.

Another scarcely suspected loss, not due to deficiency of stand, often takes place at harvest. This is caused by leaving the beets in open rows or piles in the field after they have been dug. As soon as the roots have been torn from the soil, rapid loss of water takes place from every portion of the plant. Therefore, whether the beets

are left untopped or are topped and thrown in small piles or windrows, according to custom, the wind and sunshine cause the beets to lose weight. It has been shown that the loss in weight so occasioned may exceed 5 per cent a day for several days in succession, the percentage of loss gradually decreasing as the water is progressively withdrawn from the beets.

This circumstance could be taken advantage of when beets are dug which are found not to have attained the required percentage of sucrose. The water is withdrawn by evaporation, but the sugar is not. Therefore, a concentration of sugar would take place in consequence of the evaporation of a portion of the water by permitting the beets to dry out through exposure in the field after digging. This, doubtless, would soon be sufficient to augment the sugar percentage to the required degree.

SUMMARY.

A striking variation in the yield of sugar beets on the different farms in any particular beet district of the United States, even though of very restricted area, may be noted every season.

Since the climatic factors are practically uniform in such a restricted area or district, with cultural methods almost identical and soil types within that area not very diverse, additional causes for these great variations in yield are to be sought.

Employing as a basis for comparison the stand which experiment and experience have shown to be the optimum—subject to some modification for different soil conditions—namely, a stand containing 39,200 plants per acre, which would result by leaving beets 8 inches apart in rows 20 inches apart, these studies show that even among experienced beet growers, many of them truck growers, deficiencies in stand exist to an extent quite unsuspected.

These deficiencies of stand may be divided into three groups: (1) Those occurring in the germination stand, averaging 19.32 per cent among the plats of 1912; (2) those due to improper spacing and thinning, averaging 27.3 per cent among the plats of 1911 and 23.27 per cent in 1912; and (3) those occurring between thinning and harvest, ranging from 2.54 to 12.85 per cent, with an average of 7.26 per cent among the 18 plats from which these data were obtained. Together these represent a total mean deficiency of stand of more than 50 per cent.

Most of these losses in stand can be greatly reduced by the application of better methods or a more careful adherence to already existing ones, by the more thorough supervision of hired labor, and by the elimination of contract work as far as possible. The losses may be considered as largely the result of inexperience and inefficiency. This is emphasized by the fact that as a rule where losses from one source are great, those from other sources are correspondingly large.

The data here presented show a strong correlation between percentage of stand and yield. The existence of a relation between yield and percentage of stand has been demonstrated frequently under experimental conditions in Europe and rather less frequently in the United States. Therefore, it is believed that the losses in stand shown to take place progressively throughout the season correspond to a loss in yield. However, it is also shown, through apparent exceptions to this correlation, that despite a stand of fair percentage at the outset the yield may remain comparatively small through neglect and carelessness during the season.

There is found to be a moderate uniformity in methods, but great irregularity and discrepancy are conspicuous in the thoroughness of their application; in other words, efficiency varies greatly.

It is not to be expected that every beet grower, although he may possess fields well adapted to beet culture, can at once obtain such yields as the best of those mentioned in this paper. However, such yields should be possible on many farms when, after a few years of thorough cultivation, the fields have been worked up into equally good condition. The benefits accruing from increased yields of beets through improved tilth of the soil are especially pronounced.

These studies were made among fair and good beet growers in an old beet district whose mean yield reached the respectable total of rather more than 17 tons to the acre, while the average for the United States for 1910–11 was only 10.17 tons and that for the State of Utah, where these studies were made, was 11.42 tons per acre. The magnitude of preventable loss incurred by a very large proportion of beet growers must be amazing; in fact, it must exceed the entire cost of raising the crop.

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